Proceedings of the XI International Seminar on
Mineral Processing Technology (MPT-2010)
Editors: R. Singh, A. Das, P.K. Banerjee, K.K. Bhattacharyya and N.G. Goswami

INFLUENCE OF SHAKING TABLE PROCESS PARAMETERS ON CONCENTRATION OF CHROMITE PLANT TAILINGS

Sunil Kumar Tripathy, Y. Ramamurthy, G.P. Sahu[1], L. Panda, V. Singh and V. Tathavadkar

Research and Development Division, Tata Steel Ltd., Jamshedpur
[1]COB Plant, Sukinda

ABSTRACT

Conventional chromite beneficiation plants of India discards large tonnage of chromite values as plant tailing. In the present investigation, a typical chromite beneficiation plant tailing of Sukinda region has investigated by using wet shaking table for the effective utilisation of the natural resource. In this context, the effect of different process variables such as wash water flow rate, deck tilt angle and feed flow rate has analysed. The interactional effects between different process variables has analysed in terms of 3D response surface plots. It was found that the Cr_2O_3 content has improved to 61.37% from a feed assaying 24.26%. It was envisaged that deck tilt angle has influence major on both grade and recovery of concentrate fraction of shaking table and in case of interactional effects, the interaction between deck tilt angle and feed flow rate has major influence compared to the others. Second order quadratic equations have developed for the prediction of grade and recovery of concentrate fraction of shaking table.

Keywords*: Chromite plant tailings, Beneficiation, Gravity concentration, Shaking table.*

INTRODUCTION

Most of the heavy minerals including chromite treated in gravity concentration at different stages of upgradation[1, 2] and produces huge quantity of the tailings which composes unrecovered valuable minerals. The popularity of gravity concentration is due to their simplicity, low operating cost, easy to operate. Wet shaking table is one of the key unit operations which can help in diagnostic or amenability of the gravity concentration process for different minerals/ore. The detailed principle of shaking table has been discussed elsewhere.[3–5]

Significant research effort has focused on recovery of chromite values from the plant tailings which needs to be focused on mineral conservation, utilisation and environment protection point of view.[6] The tailing generated from the Turkish chromite beneficiation plant was treated in the multy gravity separator for producing the desirable grade.[7–10] Low grade chromite sample from Karaburhan was treated with combination of wet shaking table and multigravity separator for obtaining marketable grade.[11] A combination of multi gravity separator and column flotation has been studied for the upgradation of the plant tailing.[6] But there is negligible effort has been observed for the utilisation of Indian chromite plant tailings.

In the present research, beneficiation of Indian chromite plant tailings by wet shaking table has been studied. The influence of the key process variables such as feed rate, wash water flow rate and deck tilt angle on grade and recovery of concentrate fraction of shaking table has discussed. The interactional effects of the variables have been analysed using 3D surface plots and second order quadratic models have developed for predicting the grade and recovery of the concentrate fraction of wet shaking table.

EXPERIMENTAL

Feed material

The tailing fraction of a typical chromite beneficiation plant from Sukinda region has investigated which analyses 24.26% of Cr_2O_3, 23.51% of total iron, 13.61% of alumina, 17.58% of silica, 5.35% of MgO and 7.6% of loss of ignition having 0.7 Cr/Fe ratio. As received sample has subjected for particle size analysis and their distribution has shown in Fig. 1. It can be elucidated from the size measurement that the slime is extremely fine in nature. Substantial amount of the slime is below 25 micron (33.45% by weight).

The chemical analysis of the different size fractions were carried out and given in Table 1 which shows that the Cr_2O_3 content varies from 18.2% to 29.26%. Most of the Cr_2O_3 (about 51.18% by wt) is distributed in the size fraction –250 and +25 microns. But a huge quantity (30.56% by wt) was distributed at finer sizes i.e. below 25 micron.

Table 1: Size wise chemical analysis of the chromite tailing sample

Size (μm)	Wt% Retained	Assay Value (%)				
		Cr_2O_3	$Fe_{(T)}$	Al_2O_3	SiO_2	MgO
+600	2.47	23.76	19.2	11.8	11.21	5.8
–600+500	6.74	23.18	22.2	14.35	13.1	4.5
–500+250	11.26	18.2	21.86	16.14	18	3.7
–250+150	11.26	21.2	21.87	16.4	18.77	4.34
–150+106	8.35	27.5	18.9	14.5	17.8	6.1
–106+75	5.80	26.3	18.9	15	21.1	5.7
–75+45	8.49	24	13.23	15.93	24.36	5.45
–45+37	5.97	28.52	14.32	13.66	21.4	6.2
–37+25	6.22	29.26	15.19	12.12	18.14	6.26
–25	33.45	21	23.61	12.16	14.74	5.6

The XRD study was taken up to identify mineral phases in the chromite tailing sample. The diffractogram is shown in Fig. 2. From this figure, it can be seen that along with chromite, hematite and goethite are the major iron-bearing mineral phases whereas gibbsite, kaolinite and quartz occur as minor gangue mineral phases.

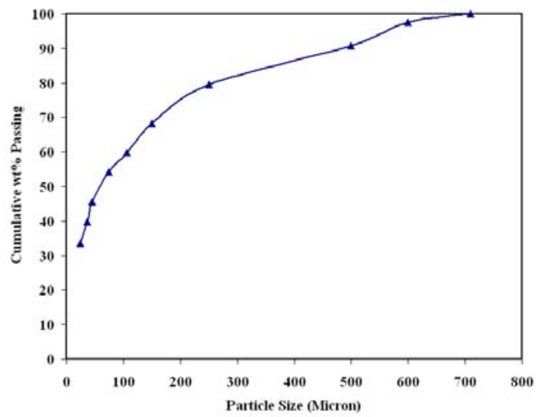

Fig. 1: Size distribution of the chromite plant tailing sample.

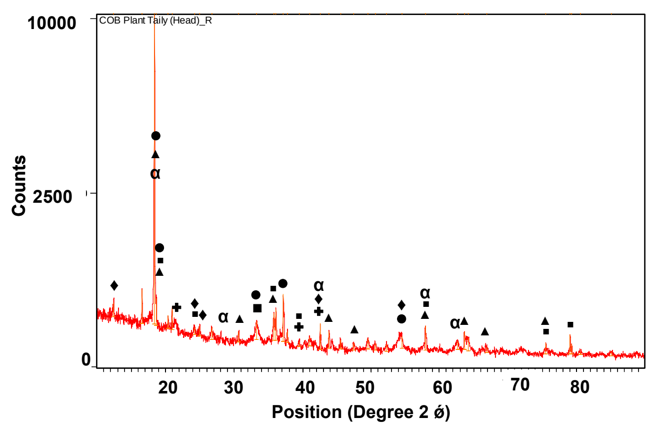

Fig. 2: X-Ray Diffraction (XRD) pattern of the tailing sample with identified phases (▲: chromite, ■:hematite, ◆: kaolinite, ●: gibbsite, ✚: quartz, α: goethite).

Methods

The experimental set up consists of feed slurry tank, a peristaltic pump and the wet shaking table. The feed slurry tank was (100-litres capacity) was attached with a stirrer to keep the solids in uniform suspension throughout the test programme. The peristaltic pump was used to feed the desired quantity of slurry to the separation unit. The laboratory shaking table used in the study is supplied by M/s The Deister Concentrator Company Inc., USA. The process variables such as wash water flow rate, deck tilt angle and feed slurry flow rate has been varied by keeping the other variables such as solid concentration at 20% solids by weight. 15 mm of shake amplitude, 200 cycles/min. of shake frequency and splitter position at 25 cm from the concentrate end were kept constant. A statistically designed test program was conducted with wet shaking table by varying different process variables. The range of operating values for each parameter tested is shown in Table 2. Number of tests has been conducted and the product samples taken from each experiment were dried, weighed and analysed in terms of grade and recovery.

Table 2: Process variable ranges used in the test programme

Process Variables	Parameter Values	
	Lower	Higher
X_1. Wash water flow rate (l/min)	2.5	7.5
X_2. Deck tilt Angle (degree)	2	6
X_3. Slurry feed Rate (l/hr)	100	160

RESULTS AND DISCUSSIONS

The experimental programme provided a broad range of grade and recovery values which envisaged that the concentrate fraction has been enriched up to with 60.88% Cr_2O_3 maximum with recovery of 13.66% whereas a maximum of 61.37% Cr_2O_3 recovery has been reported with Cr_2O_3 content of 49.58%. The test results has been analysed in further section. It is also noted that as there is an increase in the wash water flow rate from 2.5 to 7.5 lpm, there is an increase in the grade of the concentrate fraction from 42.76% to 48.95% Cr_2O_3 where as the recovery of Cr_2O_3 has drastically decreases from 57.52% to 37.33. Similarly the grade of the concentrate fraction at lower deck tilt angle (2 degree) is 42.76%. As there is an increase in the deck tilt angle, the grade has enriched to 54.86% but the recovery has significantly decreased to 12.64% from 57.52%. So it is clear that deck tilt angle has major influence on both grade and recovery of the concentrate fraction of the wet shaking table. When there is increase in the feed slurry flow rate from 100 to 160 litres/hr, the grade of the concentrate fraction has increased to 45.93% from 40.33% Cr_2O_3 but recovery has decreased to 16.4% from 33.25%.

For better understanding of the results, response surface plots has developed by using the second order quadratic equation which shows the interactional effect of process variables on grade and recovery of Cr_2O_3 in concentrate fraction of shaking table. Fig. 3 explain the effect of the process parameters of wilfley table on grade of concentrate fraction. Fig. 3(a) shows the effects of wash water flow rate (X_1) and deck tilt angle (X_2) on grade of the concentrate fraction at center level of slurry feed rate. It is observed that higher grade is obtained at lower level of wash water flow rate and higher level of deck tilt angle, which is caused due to an decrease in the residence time of the gangue minerals and that result wash away of the low density minerals to the tailing fraction.

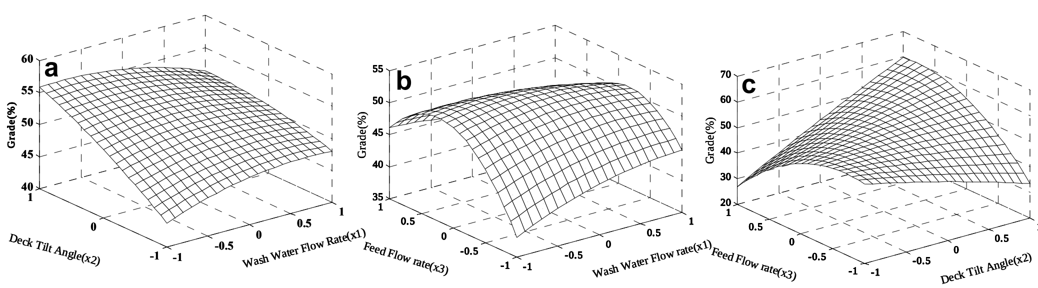

Fig. 3: Response surface plots showing the effects on grade (%) of Cr_2O_3 in the concentrate fraction: (a) Between wash water flow rate (x_1) and deck tilt angle (x_2) , (b) Between wash water flow rate (x_1) and feed flow rate (x_3), (c) Between deck tilt angle (x_2) and feed flow rate (x_3).

Fig. 3(b) explains the effect of wash water flow rate (X_1) and slurry feed rate (X_3) on grade of the concentrate fraction of the wilfley table at center level of deck tilt angle. The grade of the concentrate fraction is maximum at intermediate of slurry feed rate and lower level of the wash water flow rate. It is also observed that as the wash water flow rate increases, there is an increase in the grade of the concentrate fraction at lower level of feed flow rate and at higher level of feed flow rate and vice versa. As the wash water flow rate increases, the transport of the gangue minerals to the tailing fraction increases which in turn improves the grade of the concentrate fraction.

Fig. 3(c) explains the effect of deck tilt angle (X_2) and feed flow rate (X_3) on grade of the concentrate fraction of the wilfley table at center level of wash water flow rate. The higher grade of the concentrate fraction is obtained at higher level of both deck tilt angle and feed flow rate. It is also noted that at lower level of deck tilt angle, as the feed rate increases there is decrease in the quality of the concentrate fraction but at higher deck tilt angle, it is vice versa.

Similarly the effect of process variables on recovery of the Cr_2O_3 to the concentrate fraction of the wilfley table has been explained in Fig. 4. Fig. 4(a) demonstrate the effect of wash water flow rate (X_1) and deck tilt angle (X_2) on recovery of Cr_2O_3 in the concentrate fraction at center level of slurry feed rate. It is observed that higher recovery can be achieved at centre level of wash water flow rate and lower level of deck tilt angle which is caused as an increase in the deck tilt angle, the transport of the chromite bearing minerals along with the fines will increases, as a result recovery of Cr_2O_3 to the concentrate fraction increases. It is also noted that there is marginal effect of the deck tilt angle compared to the wash water flow rate on the recovery of the concentrate fraction.

Fig. 4(b) explains the effects of wash water flow rate (X_1) and slurry feed rate (X_3) on recovery of Cr_2O_3 in the concentrate fraction of the wilfley table at center level of deck tilt angle. The recovery of the concentrate fraction is maximum at intermediate level of both feed flow rate and wash water flow rate. As the wash water flow rate increases the transport of the fine chromite minerals to the tailing fraction increases which in turn decreases the recovery to the concentration fraction. Similarly as the feed flow rate increases the retention time for the segregation has been decreases.

Fig. 4(c) explains the effects of deck tilt angle (X_2) and feed flow rate (X_3) on recovery of Cr_2O_3 in the concentrate fraction of the wilfley table at center level of wash water flow rate. The higher recovery to the concentrate fraction is observed at centre level of feed flow rate and lower level of the deck tilt angle. It is also noted there is no marginal difference in the recovery of Cr_2O_3 to the concentrate fraction as the feed flow rate changes.

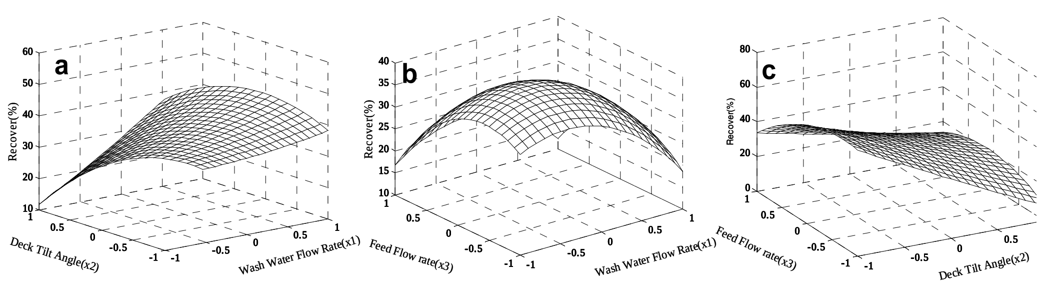

Fig. 4: Response surface plots showing the effects on recovery (%) of Cr_2O_3 in the concentrate fraction: (a) Between wash water flow rate (x_1) and deck tilt angle (x_2) , (b) Between wash water flow rate (x_1) and feed flow rate (x_3), (c) Between deck tilt angle (x_2) and feed flow rate (x_3).

For predicting the grade and recovery of concentrate fraction of wet shaking table second order quadratic models have developed and given as,

$$\text{Grade}\ (\%Cr_2O_3) = 58.07 + 9.99x_1 - 21.28x_2 + 1.89x_3 - 0.24x_1^2 - 21.28x_2^2 - 0.01x_3^2 - 0.43x_1x_2 - 0.04x_1x_3 + 0.20x_2x_3$$

$$\text{Recovery}\ (\%Cr_2O_3) = 14.87 + 2.98x_1 - 33.37x_2 + 1.80x_3 - 1.33x_1^2 + 0.21x_2^2 - 0.01x_3^2 + 1.061x_1x_2 + 0.03x_1x_3 + 0.14x_2x_3$$

The predicted grade and recovery derived by using the above equations are in good agreement with experimental datas (R^2 value between the actual and observed values for grade and recovery is 0.98 and 0.99 respectively).

CONCLUSION

Beneficiation of the chromite plant tailings by wilfley table was found to be effective equipment. It was found that the chromite can be upgraded up to 61.37% Cr_2O_3 irrespective of the recovery. It can be concluded that deck tilt angle has major influence on both grade and recovery of the concentrate fraction of the wet shaking table compared to the other variables. In case of interactional effects, the interaction between deck tilt angle and feed flow rate has major influence compared to the others. The developed second order quadratic equations can be used for predicting the grade and recovery of the concentrate fraction of the wet shaking table as the R^2 value between the actual and observed values for grade and recovery is 0.98 and 0.99 respectively.

ACKNOWLEDGEMENT

Authors are thankful to Tata Steel management for giving an opportunity to work on this project and permission to publish. The support and services provided by staff of R & D division are also duly acknowledged.

REFERENCES

[1] Demi, G., Koci, B. and Boci, S., *XXIII International Mineral Processing Congress*, Istanbul, Turkey, p. 310, 2006.
[2] Meloy, T.P., Williams, M.C., Bevilacqua, P. and Ferrara, G., Minerals and Metallurgical Processing (Part A), *SME Transactions*, **296**, p. 1870, 1994.
[3] Sivamohan, R. and Forssberg, E., Principles of tabling, *International Journal of Mineral Processing*, 15 (1985), p. 281.
[4] Falconer, A., Physical Separation in Science and Engineering, 2003, **12**, No. 1, p. 31.
[5] Burt, R., 1984, Gravity Concentration Technology. Elsevier Science.
[6] Guney A., Onal G. and Atmaca T., *Minerals Engineering*, **14**, No. I I. p. 1527, 2001.
[7] Cicek, T.C. and Cocen, I., *Minerals Engineering* 15, p. 91 (2002).
[8] Ozkan, S.G. and Ipekoglu, B., 17th International Mining Congress and Exhibition of Turkey- IMCET2001, p. 765, 2001.
[9] Cicek, T., Cocen, I. and Samanli, 1998, Innovation in Mineral and Coal Processing, p. 731, Atak, Onal and Celik (eds), Balkema, Rotterdam, The Netherlands.
[10] Belardi, G., Sheau, N., Plescia, P. and Vegilo, F., Minerals and Metallurgical Processing, Aug. 1995, p. 161.
[11] Sonmez, E. and Turgut, B., 1998, Innovation in Mineral and Coal Processing, p. 723, Atak, Onal and Celik (eds), Balkema, Rotterdam, The Netherlands.